

Ontario Geological Survey
Aggregate Resources Inventory Paper 55

**AGGREGATE RESOURCES INVENTORY OF
LONDON TOWNSHIP
Middlesex County
SOUTHERN ONTARIO**

by
Staff of the Engineering and Terrain Geology Section
Ontario Geological Survey

1983



**Ministry of
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Resources**

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Terrain Geology Section of the Ontario Geological Survey, Ontario Ministry of Natural
Resources, 77 Grenville Street, Toronto, M5S 1B3, Telephone (416) 965-1182.

Project Supervisor: Dale W. Scott
Text Prepared by: Elaine Garnet
Compilation and Drafting by: Staff of the Aggregate Assessment Office

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ABSTRACT

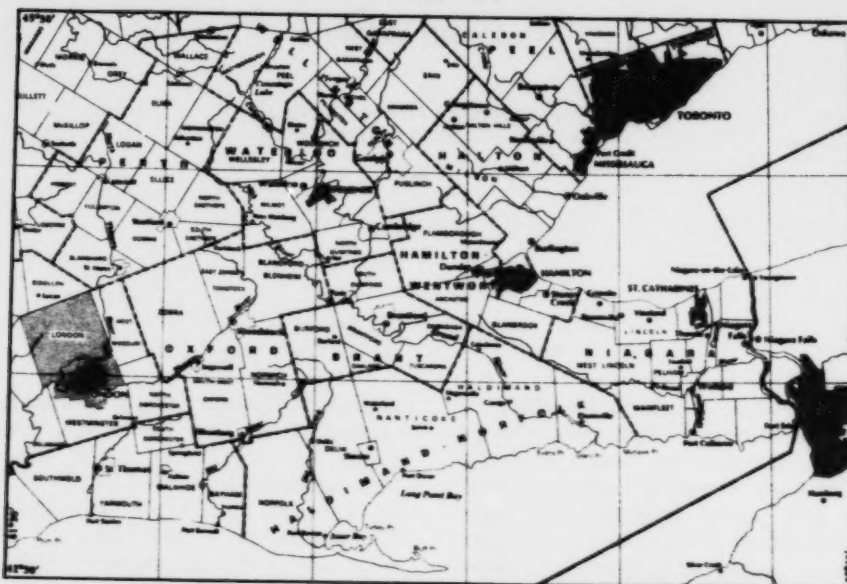


Figure 1 - Key Map Showing the Location of London Township, Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in London Township. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under The Pits and Quarries Control Act, 1971.

Data analysis has resulted in the selection of seven sand and gravel deposits for possible resource protection in London Township. The Selected Sand and Gravel Resource Areas occupy 2550 acres (1030 ha), exclusive of licenced properties. An estimated 1090 acres (440 ha) are currently available for extraction, containing approximately 75 million tons (68 million tonnes) of granular material. The parts of the Selected Areas which are available for extraction represent 13 percent of the township's total acreage of sand and gravel and 17 percent of the original tonnage.

Selected Sand and Gravel Resource Areas 1, 2, 3, and 4 are gravel outwash deposits which form part of the Fanshawe Delta. Total resources are estimated to be 47 million tons (43 million tonnes) of aggregate acceptable for a range of granular base course and hot-laid asphaltic products.

Selected Sand and Gravel Resource Area 5 is sandy ice-contact stratified drift associated with the Seaforth Moraine in the northwest corner of the township. Resources total approximately 6 million tons (5 million tonnes) of aggregate acceptable for granular base course

and hot-laid products.

Selected Sand and Gravel Resource Areas 6 and 7 are part of the gravel and sand outwash found along the Medway River meltwater channel. Total resources are approximately 16 million tons (14 million tonnes) and 6 million tons (5 million tonnes), respectively. The materials are acceptable for a variety of aggregate products.

Two deposits were selected as Resource Areas of Secondary Significance. These deposits, along with the remaining sand and gravel sources should be considered as part of the township's total aggregate supply.

Within the City of London, urban and suburban development has sterilized considerable resources of granular material. The remaining resources are constrained by new subdivisions and zoning by-laws.

The surficial deposits of London Township are underlain by limestone of the Dundee Formation. Although the formation is suitable for crushed stone and the manufacture of portland cement, the thickness of drift cover prohibits extraction.

Selected Resource Areas are not intended to be permanent, single, land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.



AGGREGATE RESOURCES INVENTORY OF LONDON TOWNSHIP¹

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1979, the total tonnage of mineral aggregates extracted was 144 million tons (131 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1980).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use

of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

¹ Manuscript accepted for publication by Chief Engineering and Terrain Geology Section, April 28, 1982. This paper is published with the permission of E.G. Pye, Director, Ontario Geological Survey.

PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). Wherever possible, field examination of potential resource areas was also undertaken to confirm interpretations made in the office. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-size fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Air photos at various scales were used to determine the continuity of deposits, especially in areas of limited subsurface information.

In the office, the pit data were supplemented by information on file with the Engineering Materials Office of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some

areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows: First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot thick layer of sand and gravel, one acre in extent, assuming an average density of 110 pounds per cubic foot.

$$\text{Tonnage} = \text{Area} \times \text{Thickness} \times \text{Density Factor}$$

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 represent only those parts of the deposit lying outside licenced areas (Column 2).

Two successive subtractions are made from the unlicensed area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas lying outside of licensed properties that have previously been extracted (e.g. wayside pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favourable bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of a workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot thick section of dolostone, one acre in extent, assuming a bulk density of 165 pounds per cubic foot).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot or approximately 3200 tons per acre. Shale resources are calculated on the basis of a bulk density estimate of 150 pounds per cubic foot.

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregates are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p. 7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

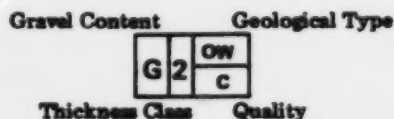
PART II - DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the distribution of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Map 1 is derived directly from the existing surficial geology maps of the area or from air photo interpretation where surficial mapping is incomplete. It shows the extent of sand and gravel deposits within the study area and serves as a base for the calculation of the total sand and gravel resources.

Map 1 presents a summary of all available information related to the quantity and quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbol which identifies each deposit. The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for a given deposit. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess fines may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class"

are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identify the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identify the main quality limitations that may be present in the deposit as discussed in the next section.

The other information presented on Map 1 is designed to give an indication of the present level of extractive activity in the study area. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating under authority of a permit) are also identified and numbered on Map 1 and described in Table 2.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. These areas are identified on Map 2 by different shading patterns.

Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by a medium-grey tone on Map 2.

Selected Aggregate Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by a light grey tone on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the aggregate supply of the municipality.

Areas of tertiary significance are indicated on the map by a dashed line but have no grey tone. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extraction development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The "gravel content", (G or S), indicates the suitability of aggregate for various uses. Deposits containing more than 35 percent crushable gravel are considered to be favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess "fines" or high silt and clay content may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fine content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent "oversize" particles (those greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building

aggregate, so must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is "lithology". Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C" "O" or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of those natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent

man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3.

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report but readers are encouraged to discuss them with personnel of the Ontario Ministry of Natural Resources' District Office.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain at roughly the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological

data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, bedrock topography, drift thickness maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources), and from geotechnical well data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the labelled bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three tones. The darkest tone indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance due to their easy access. The medium tone indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest tone indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and licenced acreage of the quarry and an estimate of face height. Un-licenced quarries (abandoned quarries or

wayside quarries operating under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and use of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of bedrock resource areas has been restricted to a single level of significance. Three factors support this approach. Quality and quantity variations are gradual. The areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material. Since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The wider range of possible resource areas allows greater flexibility in locating quarry operations away from areas of intensive land use competition. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to

exist. Such a resource area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN LONDON TOWNSHIP

LOCATION AND POPULATION

London Township occupies a roughly rectangular area of 84,960 acres (34 383 ha) in the northeast section of Middlesex County, southwestern Ontario. The township and the City of London are shown on the Lucan (40 P/3) and the St. Thomas (40 I/14) map sheets of the National Topographic System, at a scale of 1:50 000. The surrounding municipalities are the townships of Biddulph and McGillivray to the north, West Nisour Township to the east, the City of London and Westminster Township to the south, and Lobo Township to the west.

In 1956, the population of London Township was 30 720. When the City of London annexed the urbanized portion of the township in 1961, the population fell to 5885 (James F. MacLaren Ltd. 1976). The population figures have since remained fairly stable, although there has been a slight decline from 5955 in 1971 to 5779 in 1980 (James F. MacLaren Ltd. 1976; Ontario Ministry of Intergovernmental Affairs 1981). Projections to the year 2001 indicate an increase in growth for all townships in Middlesex County (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1976).

There are no major urban centres within London Township, although there are a number of small, unincorporated hamlets, such as Arva, Ballymote, Birr, Ilderton, and Denfield. The township is largely rural in character, with a significant rural-residential sector.

The proximity of the City of London (1980 population 261 841, Ontario Ministry of Intergovernmental Affairs 1981) has a considerable effect on the township in terms of land use activity and traffic flows. For example, the bulk of rural-residential development has taken place on the outskirts of the city. In addition, the most heavily travelled roads are those that serve the urban area. As the city grows in commercial importance to southwestern Ontario, added strain will be placed on local aggregate reserves to produce sand and gravel for road building and construction. The current pace of urban growth has already sterilized potential resource areas in both the city and the township. Indications are that this trend will continue unless wise resource management techniques are put into practice.

Access to sand and gravel resources within the township is provided by both paved and gravel-surfaced roads, as well as by King's Highways 4, 7, and 22. Highway 401 passes to the south of the City of London, providing access to markets throughout southwestern Ontario. The Exeter branch of the Canadian National Railways provides freight service through Denfield and Ilderton to Hyde Park where a junction with the Strathroy branch occurs. The Canadian Pacific Railway main line between Toronto and Windsor runs through the City of London.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

London Township has a flat to gently rolling land surface dissected by Oxbow Creek, Medway River and their tributaries. Fanshawe Lake occupies a small area in the southeast corner of the township and several terraces exist between the lake and the old banks of the Thames River. The physiography of the township and land use activities are further discussed by Chapman and Putnam (1966). The reader is specifically referred to descriptions of three major physiographic regions: the Stratford Till Plain (pp. 210-214), the Oxford Till Plain (pp. 231-233), and the Caradoc Sand Plains and the London Annex (pp. 236-238).

The current landscape and the distribution of surficial materials are a result of glacial events which occurred mainly during the Port Bruce Stadial of the Late Wisconsinan, approximately 15 000 to 14 000 years ago. Major thrusts from an ice lobe located in the Lake Huron basin deposited several layers of Tavistock Till — a gritty, clayey to sandy silt till — over much of the township (Sado 1980). The till is interlain with fine glaciolacustrine sediments produced during successive melting of the ice lobe. Landforms associated with the Tavistock Till are the Cherry Grove and Arva moraines located in the southeast quadrant of the township. The fine-grained nature of this till makes it unsuitable for any granular use.

During the latter part of the Port Bruce Stadial, the Huron ice readvanced and deposited the Rannoch Till — a moderately stony, silt to clayey silt till, characterized by a high limestone pebble count (Sado 1980). The Rannoch Till is

associated with the Mitchell, Lucan, and Seaforth moraines located in the western half of the township. These moraines may contain cores of gravelly material overlain by a considerable thickness of the fine-grained till which is not suitable for aggregate.

The surface of the till plains was mantled by lacustrine sediments deposited in glacial lakes formed during the melting of the Huron lobe. The sediments consist of fine gravel, sand, silt, and clay, and are thinly deposited over much of the township. A low, flat plain at Elginfield is representative of a small glacial lake which was formed between the confining ridges of the Lucan and Mitchell moraines (Sado 1980). Generally, these lakes were short-lived and left no evidence of shoreline features.

Meltwater channels were incised into the surface throughout the various stages of glacial retreat. These channels contain significant quantities of outwash consisting of well sorted, flat-lying beds of fine sand to bouldery gravel (Sado 1980). The North Thames River valley was a former meltwater channel and is an important source of aggregate. Meltwaters deposited beds of fine sand and silt into a water-filled basin. The City of London is situated on these deposits. The gravelly outwash flanking Fanshawe Park was originally deposited as a delta into glacial Lake London. As water levels retreated westward, the early Thames River cut down through the delta forming a succession of terraces and spreading gravelly alluvium over the basin. A second important meltwater channel is now occupied by the Medway River. Recent field investigation has revealed a considerable depth of coarse aggregate in this channel. There is also a thick deposit of sand and gravel in an older meltwater channel flanking the eastern side of the Seaforth Moraine in the northwest corner of the township. However, this material is overlain by thick layers of lacustrine silts.

Deposits of ice-contact stratified drift are found within and off the flanks of the Seaforth, Mitchell and Lucan moraines. Materials in the ice-contact features are extremely variable, having been formed in close proximity to the melting ice. The sand and gravel in these deposits are usually capped by till.

Glacial activity after the Port Bruce Stadial has been of minor importance. During the recent

past, the sand, silt, and gravel deposited along fluvial channels are of particular note. The floodplain alluvium of Medway River and Oxbow Creek, for example, is predominantly silty, but may contain some poorly stratified sand and gravel (Sado and Vagners 1975).

EXTRACTIVE ACTIVITY

A total of thirty-eight sand and gravel pits were identified in London Township, including many that are partly overgrown and currently inactive. At present, thirty of the pits are licenced to operate under The Pits and Quarries Control Act, 1971. The licenced properties have a total area of 1681.7 acres (680.6 ha) and are largely concentrated in the Fanshawe Delta, with lesser centres along the Medway River and to the south of Denfield. Although two properties remain to be opened, the overall level of active extraction in London Township is low. Most of the licenced pits are stockpiled, and several properties have operating asphalt or cement plants. One property is a licenced clay pit with a brick and tile plant on the premises.

Eight licenced properties, totalling 246.9 acres (99.9 ha), operate within the City of London. The properties to the southeast of Byron are deep pits undergoing extensive extraction. Expansion will be constrained by the surrounding suburban development and land currently zoned for agricultural use.

Total production figures from licenced sources have been compiled annually by the Aylmer District Office of the Ontario Ministry of Natural Resources since designation of the township in 1971. The average annual production for pits in London Township between 1972 and 1978 was approximately 1.5 million tons (1.4 million tonnes). In the same period, the average annual production from pits in the City of London was approximately 1.2 million tons (1.1 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates the deposits which contain granular material in both London Township and the City of London.¹ The total extent of these deposits in the township is approximately

1. The resource calculations on Tables 1 and 3 do not include deposits within the City of London.

8500 acres (3450 ha), representing an original tonnage of 440 million tons (400 million tonnes). Many of these potential resources have limited value for reasons of deposit size, thickness or quality of the material. Consequently, only the most significant sources are suggested for possible protection.

The sources of primary value are all related in origin to glacial meltwater channels. Six outwash deposits belonging to the Fanshawe Delta and the Medway River contain good-quality aggregate to a depth exceeding 20 feet (6 m). The ice-contact deposit to the south of Denfield is associated with a filled meltwater channel which occurs along the eastern flank of the Seaforth Moraine. Aggregate in the ice-contact feature is more variable in composition and the overall depth may not exceed 15 feet (5 m).

Sources of secondary value include an outwash deposit to the west of Ballymote and a valley train in the southwest corner of the township, flanking the north bank of the Thames River.² Although these are not the "best" sources, they should be considered as part of the township's aggregate supply.

Other sources are relatively less important and are classed at the tertiary level. Of interest, is a clay deposit approximately 20 feet (6 m) deep, located to the south of Elginfield. This feature has been described by Sado (1980) as representative of an old glacial lake. The silty, calcareous clay has the properties which make it a valuable source of material for the brick and tile industry (Guillet 1967). A licenced clay pit was opened for this purpose south of Elginfield.

In sum, seven deposits have been selected at the primary level. These sources have a combined area of 2550 acres (1030 ha), exclusive of licenced properties. One thousand and ninety acres (440 ha) are currently available for extraction. Total aggregate resources are estimated to be 75 million tons (68 million tonnes) or 17 percent of the original tonnage.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Sand and Gravel Resource Area 1 is a gravelly outwash deposit associated with the formation of the Fanshawe Delta. A large portion of the Area's 2600 acres (1050 ha) are currently under extraction or are in varying stages of rehabilitation. The area remaining for extraction includes

the parklands bordering Fanshawe Lake. The Upper Thames River Conservation Authority has jurisdiction over this park and any extractive development within the parklands could only proceed in accordance with the Authority's policies and wishes.

The Resource Area has extensive deposits of horizontally bedded, well sorted sand and gravel overlain by occasional layers of sandy silt. Water well and bore hole data indicate sand and gravel to a depth of 30 to 50 feet (9 to 15 m), thinning towards the lake, and often terminating in layers of clayey, silt till (Golder Associates 1979, p.8). The beds vary in thickness and composition throughout the area reflecting their deltaic mode of origin.

Field investigation of the various properties confirms a north-south gradation in the deposit's composition. Gravel content in the northern pits varies from 60 to 70 percent, although some sections expose finer material. Fifteen- to 20-foot (5 to 6 m) faces in pit no. 12 expose horizontally bedded, well sorted coarse gravel layers, loosely cemented with sand. The pebbles are well rounded and are 2 to 5 inches (5 to 13 cm) in diameter. The interbedded layers of sand are fine to medium grained. Gravel content in the more southerly pits is noticeably less, varying from 50 to 60 percent. A 10-foot (3 m) face in pit no. 18 exhibits horizontal layers of fine gravel less than 1 inch (25 mm) in diameter, mixed with medium sand and interbedded with fine to silty sand. Other pits, such as pit no. 25, show prominent cross-bedding.

In general, aggregate quality is good. Oversize material is sometimes present in objectionable quantities in the northern pits, and must be removed prior to crushing. In places, such as pit no. 23, the aggregate has a high chert content which makes the product undesirable for surface paving and structural concrete use. Chert content may be reduced by selective screening of the aggregate, removing the particle sizes in which chert is most often found. The high silt content in the southern pits makes it necessary to wash the aggregate in order to remove fines. Despite these limitations, the aggregate in Resource Area 1 is acceptable for Granular Base Course (G.B.C.) A and hot-mix stone where

2. "Valley train" is a term used by Dreimanis (1964, 1970). On Map 1, the deposit is shown as outwash (OW).

there is crushable material and G.B.C. B and C or asphalt sand where the material is finer (Deike 1976).

Resource Area 1 occupies approximately 1120 acres (455 ha), exclusive of licenced areas. Allowances for cultural setbacks and areas previously extracted reduce this figure to 430 acres (174 ha). Assuming a deposit thickness of 35 feet (11 m), estimated sand and gravel resources are 38 million tons (34 million tonnes). The Area is well situated with respect to London's urban market and is served by several paved county roads.

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Sand and Gravel Resource Area 2 is a gravel outwash deposit of 175 acres (71 ha). This area is also a part of the Fanshawe Delta and has many characteristics in common with Resource Area 1. However, there are several reasons for which Area 2 merits separate selection.

There are two licenced properties in the deposit with face heights ranging from 10 to 20 feet (3 to 6 m). Pit no. 11 exhibits horizontal layers of fine to medium-coarse gravel, interbedded with medium to coarse sand. The bedding is not as distinct as in the pits to the southwest and the material is not as well sorted. Gravel content, however, is high in both pits, ranging from 60 to 70 percent. A large central block in pit no. 14 is composed of coarse gravel strongly cemented with calcium carbonate. Excavation had proceeded around and excluded this solid mass. Calcium carbonate cementation is common in the area (E.V. Sado, personal communication, 1980). Oversize material is also present in quantities up to 15 percent.

Golder Associates (1979) note extensive strata of sand and gravel in this area. A bore hole to the east in West Nissouri Township was terminated after penetrating 30 feet (9 m) of granular material (Golder Associates 1979, p.9). Despite the more negative aspects of the material exposed in the licenced properties, there is evidently good-quality aggregate remaining in the deposit. Data obtained from the Ontario Ministry of Transportation and Communications (M.T.C.) indicate the material is acceptable for granular base course products and hot-laid stone.

Resource Area 2 measures 90 acres (36 ha), exclusive of the licenced properties. Setback

allowances reduce this area to 30 acres (12 ha) currently available for extraction. Assuming an average deposit thickness of 25 feet (8 m), estimated sand and gravel resources total 2 million tons (2 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Sand and Gravel Resource Area 3 is a small section of the Fanshawe Delta. The deposit is gravel outwash and extends into West Nissouri Township. There are currently no pits in the area.

Golder Associates (1979, p. 9) note that up to 5 feet (2 m) of sandy silt overlie strata of sand and gravel ranging in thickness from 3 to 15 feet (1 to 5 m). Fifty to 70 percent of the material is greater than fine gravel and up to 20 percent is cobble sized (Golder Associates 1979, Fig. 9).

Resource Area 3 is 68 acres (28 ha) in size, but only 23 acres (9 ha) are available for extraction. Water well data show that the deposit depth exceeds 30 feet (9 m). However, a more conservative estimate of 25 feet (8 m) was used to calculate the resource tonnage. Sand and gravel resources are approximately 1 million tons (1 million tonnes). Access to London Township is somewhat constrained by the deposit's location on the east side of Fanshawe Lake.

SELECTED SAND AND GRAVEL RESOURCE AREA 4

Sand and Gravel Resource Area 4 is a section of the Fanshawe Delta to the south of the Thames River. Water well data show sand and gravel to a depth of 20 to 30 feet (6 to 9 m). There are two licenced and two unlicenced pits; all of which are largely depleted. Although more material may be available, extraction will be constrained by the Thames River to the north and the City of London to the south.

From field observation, this deposit is similar in composition to the finer grained, southern section of Resource Area 1. The licenced properties (pit nos. 29 and 30) have mainly sand remaining. A 15-foot (5 m) face in pit no. 30 shows only a 20 percent gravel content. The gravel is well rounded and the sand is medium to coarse grained. Pit no. 29 exhibits some oversize and both pits have silty sections.

Sado (1976, p.9), however, noted that coarse aggregate greater than 65 percent is available in

multiple beach terraces which parallel the river. These terraces have been used as sources of crushable aggregate in the past. A 10- to 12-foot (3 to 4 m), sloughed face at pit no. 41 reveals a gravel content of 60 to 70 percent, with a maximum gravel size of approximately 3 inches (8 cm) in diameter. The sand is medium to coarse with some silty sections.

Resource Area 4 occupies 440 acres (178 ha), exclusive of the licenced areas. Allowances for setbacks and previous extraction leave 110 acres (44 ha) currently available for development. Assuming a depth of 20 feet (6 m), sand and gravel resources are estimated to be 6 million tons (5 million tonnes). The aggregate is acceptable for a wide range of road building and construction products.

SELECTED SAND AND GRAVEL RESOURCE AREA 5

Sand and Gravel Resource Area 5 is a 290-acre (117 ha), sandy, ice-contact stratified drift deposit located to the northwest of Ilderton. This till-capped deposit was formed in association with the Seaforth Moraine and in close proximity to the melting ice margin. As a result, the material is highly variable and difficult to evaluate.

Three licenced properties (pit nos. 6, 7 and 8) reveal little evidence of bedding and the granular material is poorly sorted. Face heights range from 8 to 15 feet (2 to 5 m) and expose material with a 60 to 70 percent gravel content. Maximum particle size is approximately 6 inches (15 cm). Data obtained from the M.T.C. give a lower gravel content of 50 to 55 percent. Although these findings tend to confirm a gravel source, the crushable aggregate is variable in occurrence and testing would be required to locate a site capable of supporting a commercial operation. The material is suitable for G.B.C. A, 5/8 inch (16 mm) crushed stone and hot-laid stone. The sand tends to be "dirty" and coarse and would require blending for hot-laid asphaltic sand (Deike 1976).

Resource Area 5 occupies 240 acres (97 ha), exclusive of the licenced properties. Setback allowances reduce this figure to 150 acres (61 ha). Assuming a deposit depth of 15 feet (5 m), possible resources are approximately 6 million tons (5 million tonnes). Recent subsurface testing in the area suggest this is a maximum tonnage (E.V. Sado, personal communication, 1980).

SELECTED SAND AND GRAVEL RESOURCE AREA 6

Sand and Gravel Resource Area 6 is 485 acres (196 ha) of gravel outwash located along the meltwater channel now occupied by the Medway River. This deposit has supported several extractive sites in the past and can be an important source of aggregate in the future for the northern part of the township.

At present, information about the granular material is provided by five pits. Face heights in pit nos. 2, 3 and 4 range from 5 to 15 feet (2 to 5 m) and expose, fine to coarse gravel mixed with coarse sand. The gravel content varies from 30 to 60 percent. Variability is evident in pit no. 2 where the gravel occurs in lenses overlain by sand. In all of the pits, the bedding is not very distinct and the sorting is poor to fair. The material is acceptable for G.B.C. A, 5/8 inch (16 mm) crushed stone, and hot-laid stone. The sand tends to be "dirty" and would require blending for hot-laid uses.

All of the pits contain ponded water, indicative of the area's high water table. Recent drilling has revealed 27 feet (8 m) of coarse aggregate in the deposit (E.V. Sado, personal communication, 1980). Therefore, further extraction will have to take place by draglining material from below the water levels.

Resource Area 6 occupies 400 acres (162 ha), exclusive of the licenced properties. Setback allowances and the amount of previous extraction reduce the area presently available to 250 acres (101 ha). Assuming a deposit thickness of 25 feet (8 m), sand and gravel resources are approximately 16 million tons (14 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 7

Sand and Gravel Resource Area 7 extends along the Medway River to the north of Resource Area 6. This section of the old meltwater channel is predominantly sand outwash.

Several extractive sites are evident, although they are shallow, overgrown and water filled. A widening of the Medway River in the northern half of the deposit was once a site where about 30 feet (9 m) of gravelly sand was removed and the stream allowed to fill in the depression (E.V. Sado, personal communication, 1980). A small pit in Biddulph Township to the north is

representative of this material. A 10-foot (3 m) face exposes approximately 3 feet (1 m) of clayey sand underlain by poorly sorted fine gravel and coarse sand. The gravel content varies between 30 and 50 percent. In London Township, this deposit would require testing to confirm its composition. Limited data suggest the material is suitable for G.B.C. A and B, and hot-laid sand and stone. Silty sections and the high water table may be limiting factors.

Resource Area 7 occupies 200 acres (81 ha), of which 100 acres (40 ha) are currently available for extraction. Assuming a deposit thickness of 25 feet (8 m), sand and gravel resources are estimated to be 6 million tons (5 million tonnes).

SAND AND GRAVEL RESOURCES OF SECONDARY SIGNIFICANCE

To the west of Ballymote, is a gravel outwash deposit which Deike (1976) has termed a "potential aggregate area". One water well shows sand and gravel to a depth of 21 feet (6 m) and Fraser (1974, p. 9) states that the material may be suitable for... "moderate amounts of subgrade aggregate and asphaltic concrete sand."

A second resource area is located in the extreme southwest corner of the township. This belt of sandy outwash is shown as a "valley train" by Dreimanis (1964). Water well data confirm the material is sand. Deike (1976) has shown the eastern lobe as a "potential aggregate area".

SAND AND GRAVEL RESOURCES WITHIN THE CITY OF LONDON

During the Late Wisconsinan, the London basin received large quantities of deltaic and outwash sediments from melting glacial ice. These deposits contain sand and gravel to great depths and there are a number of old and new extractive sites within the limits of the City of London. Most of the deposits are now covered with urban and suburban development and few areas remain in which to adequately exercise resource management controls.

One such area is the Byron deposit. Here, several licenced properties extract granular material with a gravel content of 50 to 60 percent. Fine to medium gravel and coarse sand

occur in distinct lenses, interbedded with fine to medium sand. Some sections contain large blocks of gravel cemented with calcium carbonate. Generally, M.T.C. data suggest the material is acceptable for a variety of granular base course and hot-laid products.

The Byron properties are currently zoned "industrial". Expansion is constrained by the surrounding suburban development and land zoned "agricultural" to the south. Extraction has taken place to a depth of approximately 200 feet (61 m). This depth of extraction will make the pits difficult to rehabilitate as considerable space will be required to grade the slopes to the degree recommended in Ontario Regulation 545/71 of The Pits and Quarries Control Act, 1971. If aggregate extraction is to be an integral land use activity within the City of London, such problems must be solved to the satisfaction of all concerned.

BEDROCK GEOLOGY

London Township is underlain by bedrock of the Dundee Formation. This formation consists of 60 to 160 feet (18 to 49 m) of light brown, medium-grained limestone with some chert present (Hewitt 1972, p. 12). The limestone is quarried near St. Marys in Blanshard Township for the manufacture of portland cement. Elsewhere in southwestern Ontario, the formation is quarried for crushed stone.

Although quarries once existed along the Thames River valley within the City of London limits, excessive drift thickness has prohibited extraction in London Township. Drift thickness exceeds 150 feet (46 m) and in some areas 200 feet (61 m). A notable exception is in the southeast where drift thickness on the shores of Fanshawe Lake and in a small area along the Thames River is less than 50 feet (15 m). These two areas have not been suggested for possible resource protection because of cultural and physical constraints associated with the Thames River and Fanshawe Lake.

SUMMARY

The sand and gravel deposits of London Township are the product of glacial activity which occurred during the Late Wisconsinan. Primary resource areas are outwash and ice-contact deposits related to former meltwater channels. The resource areas contain good-

quality aggregate in commercially viable quantities. Secondary and tertiary deposits are additional sources of aggregate which may be used to supplement the primary areas at the discretion of the municipality. Aggregate resources within the City of London have been largely sterilized by urban development.

The current level of active extraction is low, with pit operators working from previously excavated stockpiles. As growth in the London area continues, urban sprawl and the demand for aggregate will put pressure on those deposits demonstrated to contain sand and gravel. Resource management strategies should be devised in order to protect and/or wisely develop remaining resources both in London Township and the City of London.

Limestone from the underlying Dundee Formation has been used elsewhere in southwestern Ontario for crushed stone and in the manufacture of portland cement. Drift thickness in London Township is too great to permit extraction.

Enquiries regarding the Aggregate Resources Inventory of London Township should be directed to the Ontario Ministry of Natural Resources at the Aylmer District Office, 353 Talbot Street West, Aylmer, Ontario, N5H 2S8 (Tel. (519) 773-9241) or at the Southwestern Region Geological Office, 458 Central Avenue, London, Ontario, N6B 2E5 (Tel. (519) 433-8431).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, LONDON TOWNSHIP*

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
SAND AND GRAVEL RESOURCES			
1	G-OW	3900 (1580)	300 (270)
	S-OW	211 (85)	13 (12)
2	G-AL	171 (69)	8 (7)
	G-IC	24 (10)	1 (1)
	S-IC	790 (320)	23 (21)
	G-OW	510 (206)	23 (21)
	S-OW	1260 (510)	47 (43)
3	G-IC	400 (162)	5 (4)
	S-IC	248 (100)	5 (4)
	G-OW	435 (176)	9 (8)
	S-OW	144 (58)	2 (2)
4	S-AL	400 (162)	4 (4)
		8500 (3450)	440 (400)
CLAY RESOURCES			
1	C-LP	355 (144)	No tonnage estimate

* Identified deposit areas within the City of London are omitted on all tables.

N.B. Minor variations in above table are due to rounding of data.

TABLE 2 | SAND AND GRAVEL PITS, LONDON TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
1		Rydall Brick and Tile Ltd.	17	16	25.0 (10.1)	3 (1) above water	clay source
2		County of Middlesex	Pt. 13	15	33.8 (13.7)	8-10 (2-3)	50-60 partly overgrown
3		Towland-Hewitson Construction Ltd.	13	15	21.6 (8.7)	5-10 (2-3) above water	50-60
4		Walloy Excavating Ltd.	13	15	43.7 (17.7)	10-15 (3-5)	30-50 partly overgrown
5		McCann Construction Ltd.	Pt. 29	15	19.3 (7.8)	10-12 (3-4)	60-70
6		R.H. Jennison	Pt. 32	13	57.0 (23.1)	8-10 (2-3)	60-70
7		Corbett and Young Inc.	Pt. 31	13	43.0 (17.4)	10-15 (3-5) above water 5 (2) below water	60-65 partly overgrown and water filled
8		County of Middlesex	Pt. 32	13	2.3 (0.9)	10-12 (3-4) above water	60-70 water filled
9		South Winds Sand and Gravel Ltd.	Pt. 5	6	29.0 (11.7)	5-8 (2)	60-70 partly overgrown
10		South Winds Sand and Gravel Ltd.	Pt. 3, 4	6	85.0 (34.4)	10-15 (3-5)	60-70 partly rehabilitated
11		Township of London	Pt. 1	6	62.7 (25.4)	10-20 (3-6)	60-70 partly overgrown

TABLE 2 | SAND AND GRAVEL PITS, LONDON TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
12		J.F. Marshall and Sons Ltd.	5	6	48.9 (19.8)	15-20 (5-6)	60-70 partly overgrown
13		J.F. Marshall and Sons Ltd.	Pt. 3, 4	6	149.9 (60.7)	20-25 (6-8)	60-70 partly overgrown
14		I. McGuffin	1	6	21.8 (8.8)	15-20 (5-6)	60-70 partly overgrown
15		J.F. Marshall and Sons Ltd.	Pt. 5	5	104.0 (42.1)	12-15 (4-5)	60-70 partly overgrown
16		T.C.G. Materials Ltd.	Pt. 4	5	39.2 (15.9)	15-20 (5-6)	40-50 partly overgrown
17		South Winds Sand and Gravel Ltd.	6	5	38.0 (15.4)	15-20 (5-6)	50-60 partly overgrown
18		T.C.G. Materials Ltd.	6	5	46.0 (18.6)	5-10 (2-3)	50-60
19		T.C.G. Materials Ltd.	Pt. 5	5	102.9 (41.6)	10 (3) south section is unopened	50-60 partly overgrown
20		T.C.G. Materials Ltd.	Pt. 4	5	80.0 (32.4)	unopened	
21		Carpenter Sand and Gravel Ltd.	4	5	39.0 (15.8)	12-15 (4-5)	50-60 partly overgrown
22		R.A. Foskett	Pt. 4	5	8.7 (3.5)	5-10 (2-3)	50-60 partly overgrown
23		Matthews Group Ltd.	3	5	65.0 (26.3)	20-25 (6-8)	40-50
24		Crich Holdings and Buildings Ltd.	Pt. 6	4	100.0 (40.5)	20-25 (6-8)	50-60 partly, overgrown
18							

TABLE 2 | SAND AND GRAVEL PITS, LONDON TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
25		Towland-Hewitson Construction Ltd.	5	4	93.0 (37.6)	20-25 (6-8)	50-60
26		J.F. Marshall and Sons Ltd.	Pt. 4	4	90.0 (36.4)	15-20 (5-6)	60-70 partly rehabilitated
27		J.F. Marshall and Sons Ltd.	Pt. 3, 4	4	35.0 (14.2)	15-20 (5-6)	60-70 partly rehabilitated
28		J.F. Marshall and Sons Ltd.	Pt. 3, 4	4	70.0 (28.3)	20-25 (6-8)	40-50 partly rehabilitated
29		Matthews Group Ltd.	Pt. 7	4	86.6 (35.0)	12-15 (4-5)	overgrown faces
30		Matthews Group Ltd.	6	3	41.3 (16.7)	12-15 (4-5)	sand (nearly depleted)
					1681.7 (680.6)		
CITY OF LONDON							
31		Eadie and Willcock Ltd.	Pt. 6, 9	Plan 563 (1)	69.3 (28.0)	30-40 (9-12)	40-50 partly overgrown
32		N.J. Spivak Ltd.	Pt. 5	Plan 563 (1)	17.4 (7.0)	50-75 (15-23)	40-50
33		Corp. of the Township of Westminster	Pt. 43	Plan 563 (1)	2.9 (1.2)	25-30 (8-9)	depleted
34		Highcrest Properties Ltd.	Pt. 42	1	16.2 (6.6)	25-30 (8-9) depth of extraction is approx. 75 (23 m)	50-60 partly overgrown
35		T.C.G. Materials Ltd.	Pt. 41, 42	1	82.5 (33.4)	75-100 (23-30)	50-60
36		South Winds Sand and Gravel Ltd.	Pt. 42	1	10.1 (4.1)	75-100 (23-30) depth of extraction is approx. 200 (61)	50-60

TABLE 2 | SAND AND GRAVEL PITS, LONDON TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
37		South Winds Sand and Gravel Ltd.	Pt. 42	1	31.5 (12.8)	75-100 (23-30) depth of extraction is approx. 200 (61)	50-60
38		Matthews Group Ltd.	1	A	17.0 (6.9) 246.9 (99.9)	12-15 (4-5)	20-30 partly overgrown
UNLICENCED PITS							
39		McClure	17, 18	1		12-15 (4-5)	20 partly overgrown
40		T.C.G. Materials Ltd.	6	3		sloped	partly rehabilitated
41		Branton	8	4		10-12 (3-4)	60-70 partly overgrown
42		McGuffin	7	4		sloughed	60-70 partly overgrown
43	L7-51	D.H.O.	6	5		10-12 (3-4) sloughed	60 overgrown
44	L7-30	D.H.O.	16	12		10 (3) sloughed	60 partly overgrown
45	L7-29	Morrow	14	13		5 (2)	overgrown and water filled
46	L7-25	Walden Bros.	10, 11	16		3-5 (1-2)	overgrown and water filled
47	L7-179	Rydall Brick and and Tile Ltd.	17	16		5 (2)	overgrown and water filled

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, LONDON TOWNSHIP

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
1	1120 (455)	520 (210)	170 (69)	430 (174)	35 (11)	38 (34)
2	90 (36)	60 (24)	0 (0)	30 (12)	25 (8)	2 (2)
3	68 (28)	45 (18)	0 (0)	23 (9)	25 (8)	1 (1)
4	440 (178)	200 (81)	130 (53)	110 (44)	20 (6)	6 (5)
5	240 (97)	90 (36)	0 (0)	150 (61)	15 (5)	6 (5)
6	400 (162)	140 (57)	10 (4)	250 (101)	25 (8)	16 (14)
7	200 (81)	85 (34)	15 (6)	100 (40)	25 (8)	6 (5)
	2550 (1030)	1140 (460)	325 (132)	1090 (440)		75 (68)

N.B. Minor variations in above table are due to rounding of data.

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, LONDON TOWNSHIP

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
25-50 (8-15)	Dundee	60 (18)	355 (144)	77 (70)

N.B. Minor variations in above table are due to rounding of data.

TABLE 5 | QUARRIES, LONDON TOWNSHIP

1	2	3	4	5	6	7
NO.	MTC NO.	OWNER/OPERATOR	LOT	CON.	LICENCED AREA Acres (Hectares)	FACE HEIGHT Feet (Metres)

— NONE —

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, LONDON TOWNSHIP

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED AVAILABLE WORKABLE RESOURCES THICKNESS Feet (Metres)	8 Millions of Tons (Tonnes)
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- NONE -

REFERENCES

- Association of Professional Engineers of Ontario
1976: Performance Standards for Professional Engineers Advising on and Reporting on Oil, Gas and Mineral Properties; Association of Professional Engineers of Ontario, 11 p.
- Chapman, L.J. and Putnam, D.F.
1966: The Physiography of Southern Ontario; Second Edition, University of Toronto Press, 386 p.
- Deike, W.
1976: Mineral Aggregate Resources in the Township of London; Geotechnical Office, Ontario Ministry of Transportation and Communications, 19 p., 1 map, scale 1:50 000.
- Dreimanis, A.
1964: Pleistocene Geology of the St. Thomas Area (West Half); Ontario Department of Mines, Preliminary Map P. 238, scale 1:50 000.
1968: St. Thomas Sheet, Southern Ontario; Ontario Department of Mines, Preliminary Map P. 482, Bedrock Topography Series, scale 1:50 000.
1970: Pleistocene Geology of the St. Thomas Area (East Half); Ontario Department of Mines, Preliminary Map P. 606, scale 1:50 000.
- Fraser, J.
1974: Mineral Resource Survey, London Township, Middlesex County; Ontario Division of Mines, unpublished report, 12 p. Accompanied by 1 map, scale 1:50 000.
- Golder Associates
1979: Subsurface Investigation, Preliminary Aggregate Evaluation, Fanshawe Park Resource Inventory; Report to Upper Thames River Conservation Authority, 20 p., 3 tables, 17 figures. Unpublished report.
- Guillet, G.R.
1967: The Clay Products Industry of Ontario; Ontario Department of Mines, Industrial Mineral Report 22, 206 p. Accompanied by Maps 2130 and 2131, scale 1:1 013 760.
- Hewitt, D.F.
1972: Paleozoic Geology of Southern Ontario; Ontario Division of Mines, Geological Report 105, 18 p. Accompanied by Map 2254, scale 1:1 013 760.
- James F. MacLaren Ltd.
1976: Township of London Background Studies. Unpublished report.
- Karrow, P.F.
1965: Bedrock Topography Series, Lucan Sheet; Ontario Department of Mines, Preliminary Map P. 291, Bedrock Topography Series, scale 1:50 000.
- Ontario
1981: The Pits and Quarries Control Act, 1971; Revised Statutes of Ontario, 1980, Chapter 378, Queen's Printer for Ontario.
- Ontario Interministerial Committee on National Standards and Specifications (Metric Committee)
1975: Metric Practice Guide; 67 p.
- Ontario Ministry of Intergovernmental Affairs
1981: Municipal Directory 1981; Queen's Printer for Ontario, 191 p.
- Ontario Ministry of Natural Resources
1980: Statistics 1980; Ontario Ministry of Natural Resources, 122 p.
- Ontario Ministry of Treasury, Economics and Intergovernmental Affairs
1976: Ontario's Changing Population Volume II, Directions and Impact of Future Change — 1971-2001; Regional Planning Branch, 184 p.
- Robertson, J.A.
1975: Mineral Deposit Studies, Mineral Potential Evaluation, and Regional Planning in Ontario; Ontario Division of Mines, Miscellaneous Paper 61, 42 p.
- Sado, E.V.
1976: Granular Aggregate Inventory of London, Westminster and Lobo Townships, Middlesex County, Ontario; Ontario Division of Mines, Geological Branch, Open File Report 5182, 21 p., 8 tables, 6 maps, scale 1:25 000.

1980: The Quaternary Stratigraphy and History of the Lucan Map Area, Southwestern Ontario; Unpublished MSc. Thesis, University of Waterloo, 146 p.

Sado, E.V. and Jones, D.

1980: Drift Thickness of the Lucan Area, Southern Ontario; Ontario Geological Survey, Preliminary Map P. 2359, Drift Thickness Series, scale 1:50 000.

Sado, E.V. and Vagners, U.J.

1975: Quaternary Geology of the Lucan Area, Southern Ontario; Ontario Division of Mines, Preliminary Map P. 1048, Geological Series, scale 1: 50 000.

Sanford, B.V.

1969: Geology of the Toronto-Windsor Area, Ontario; Geological Survey of Canada, Map 1263A, scale 1:250 000.

APPENDIX A - SUGGESTED ADDITIONAL READING

American Geological Institute

1972: *Glossary of Geology*; Washington, D.C., 858 p.

Bauer, A.M.

1970: *A Guide to Site Development and Rehabilitation of Pits and Quarries*; Ontario Department of Mines and Northern Affairs, Industrial Mineral Report 33, 62 p.

Cowan, W.R.

1977: *Towards the Inventory of Ontario's Mineral Aggregates*; Ontario Geological Survey, Miscellaneous Paper 73, 19 p.

Fairbridge, R.W. (ed.)

1968: *The Encyclopedia of Geomorphology*; Encyclopedia of Earth Sciences, Vol. III, Reinhold Book Corp., N.Y., 1295 p.

Flint, R.F.

1971: *Glacial and Quaternary Geology*; John Wiley and Sons Inc., 892 p.

Hewitt, D.F.

1960: *The Limestone Industries of Ontario*; Ontario Department of Mines, Industrial Mineral Report 5, 177 p.

1964a: *Building Stones of Ontario, Part I Introduction*; Ontario Department of Mines, Industrial Mineral Report 14, 43 p.

1964b: *Building Stones of Ontario, Part II Limestone*; Ontario Department of Mines, Industrial Mineral Report 15, 41 p.

1964c: *Building Stones of Ontario, Part III Marble*; Ontario Department of Mines, Industrial Mineral Report 16, 89 p.

1964d: *Building Stones of Ontario, Part IV Sandstone*; Ontario Department of Mines, Industrial Mineral Report 17, 57 p.

1972: *Paleozoic Geology of Southern Ontario*; Ontario Division of Mines, Geological Report 105, 18 p.

Hewitt, D.F. and Karrow, P.F.

1963: *Sand and Gravel in Southern Ontario*; Ontario Department of Mines, Industrial Mineral Report 11, 151 p.

Hewitt, D.F. and Vos, M.A.

1970: *Urbanization and Rehabilitation of Pits and Quarries*; Ontario Department of Mines, Industrial Mineral Report 34, 21 p.

Lowe, S.B.

1980: *Trees and Shrubs for the Improvement and Rehabilitation of Pits and Quarries in Ontario*; Ministry of Natural Resources, 71 pg.

McLellan, A.G.; Yundt, S.E. and Dorfman, M.L.

1979: *Abandoned Pits and Quarries in Ontario*; Ontario Geological Survey, Ministry of Natural Resources, Miscellaneous Paper 79, 36 pg.

Ontario Mineral Aggregate Working Party

1977: *A Policy for Mineral Aggregate Resource Management in Ontario*; Ontario Ministry of Natural Resources, 232 p.

Ontario Ministry of Natural Resources

1975: *Vegetation for the Rehabilitation of Pits and Quarries*; Forest Management Branch Division of Forests, 38 p.

Peat, Marwick & Partners and

M.M. Dillon Limited

1981: *Mineral Aggregate Transportation Study*; Industrial Minerals Background Paper 1, 133 pg. Summary Report 26 pg.

Proctor and Redfern Ltd.

1974: *Mineral Aggregate Study, Central Ontario Planning Region*; Prepared for the Ontario Ministry of Natural Resources, over 100 p.

Proctor and Redfern Ltd., and Gartner Lee Associates Ltd.

1975: *Mineral Aggregate Study of Part of The Eastern Ontario Region*; Prepared for the Ontario Ministry of Natural Resources, about 200 p.

1977: *Mineral Aggregate Study and Geological Inventory, Southwestern Region of Ontario*; Prepared for the Ontario Ministry of Natural Resources, about 200 p.

APPENDIX B - GLOSSARY

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

CAMBRIAN

The first Period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

CLAST

An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a large rock mass. Synonyms include particle and fragment.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone, and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN

A Period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DIRT

See fines.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.074 mm). Also described informally as "dirt", these particles are in the silt- and clay-size range.

GLACIAL LOBE

A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GRADATION

The proportion of material of each particle size or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder		>256 mm
Gravel	cobble	64-256 mm
Gravel	pebble	4-64 mm
Gravel	granule	2-4 mm
Sand	coarse	.5-2 mm
	medium	.25-.5 mm
	fine	.074-.25 mm
Silt, clay		<.074 mm

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability, and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

H.L. (HOT-LAID OR ASPHALTIC AGGREGATE)

Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3, and 4), or as binder course (H.L. 2, 6, and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition, and grain size. Generally, the description of the physical character of a rock.

MELTWATER CHANNEL

A drainage way, usually terraced, produced by water flowing away from a melting glacier margin.

ORDOVICIAN

An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA

One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago. The Paleozoic Era (or Ancient Life Era) is subdivided into six geologic Periods, of which only four (Cambrian, Ordovician, Silurian, and Devonian) can be recognized in southern Ontario.

PLEISTOCENE

An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity.

POSSIBLE RESOURCE

Estimates of mineral aggregate material based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples of measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt, or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone, and mudstone.

SILURIAN

An early Period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering

processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial stage of the Pleistocene Epoch in North America. It began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 7000 to 85 000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and they can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain-size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is

unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good-quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the presence of excess fines (silt- and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. They vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout southern Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain-size variability. They are given a qualita-

tive rating based on existing pit and other sub-surface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. They occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain-size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amount of crushable aggregate in alluvial deposits is low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAIN (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. They commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

WINDBLOWN FORMS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from,

and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments are almost invariably composed of fine to coarse sand and

are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS

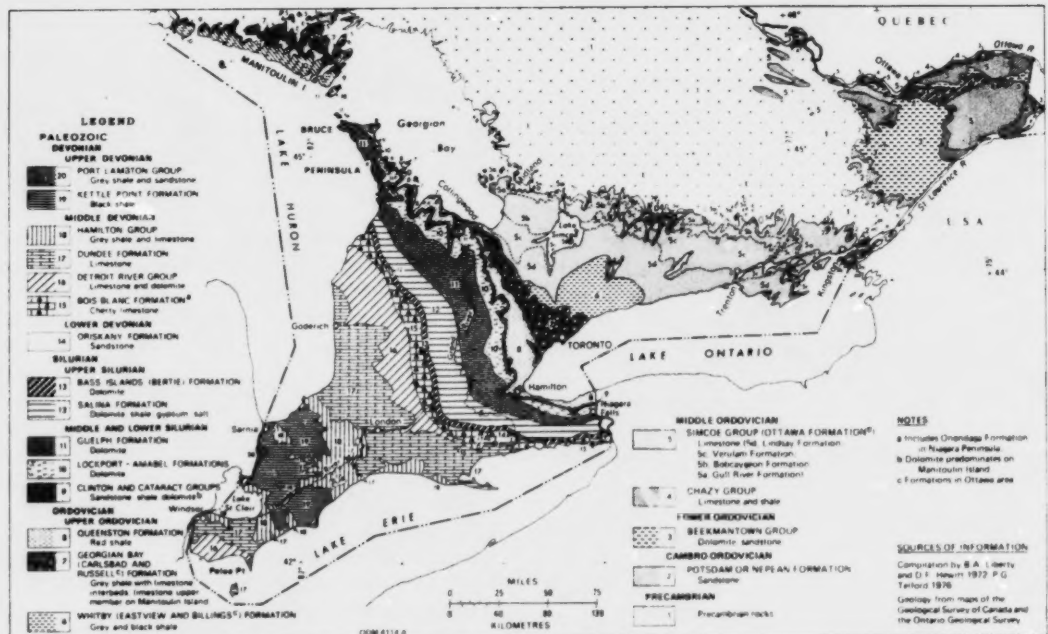


Figure 2 - Bedrock Geology of Southern Ontario

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

BASS ISLANDS FORMATION (UPPER SILURIAN)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11-18m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate due to high soundness losses.

BOBCAYGEON FORMATION (MIDDLE ORDOVICIAN)

Composition: Compact, homogeneous, medium-

to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

BOIS BLANC FORMATION (LOWER-MIDDLE DEVONIAN)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion

Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

DUNDEE FORMATION (MIDDLE DEVONIAN)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

GULL RIVER FORMATION (MIDDLE ORDOVICIAN)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County, and Uthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

LOCKPORT AND AMABEL FORMATIONS (MIDDLE SILURIAN)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Watertown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, and building stone throughout their area of occurrence, and are a valuable aggregate resource. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

ONONDAGA FORMATION (MIDDLE DEVONIAN)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliffe Member: medium-bedded, fine- to medium-

grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey brown, fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

OTTAWA FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Falls Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

OXFORD FORMATION (LOWER ORDOVICIAN)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES.

DETROIT RIVER GROUP (MIDDLE DEVONIAN)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change). Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important

source of high purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces 80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas formation is quarried at Amherstburg for crushed stone.

GRENVILLE MARBLE (PRECAMBRIAN)

Composition: Recrystallized white limestone and dolostone, fine- to coarse-grained, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazo chips, poultry grit, decorative stone, and building stone.

GUELPH FORMATION (MIDDLE SILURIAN)

Composition: Aphanitic- to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. It is quarried at Glen Christie and Guelph.

LINDSAY FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Member: fine-crystalline, rubbly, nodular, weathering limestone. Upper Member: grey calcareous claystone with shaly partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point, Colborne, and Bowmanville for lime. It is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

VERULAM FORMATION (MIDDLE ORDOVICIAN)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200-300 feet (61-91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for lime. It is unsuitable for crushed stone due to clay impurities

and many clayey interbeds, low abrasion resistance. High soundness losses and poor freeze-thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

GEORGIAN BAY FORMATION (UPPER ORDOVICIAN)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas). Composition: Soft, fissile, blue grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Five producers in Metro Toronto and Cooksville produce brick and structural tile (Guillet 1967). Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

HAMILTON GROUP (MIDDLE DEVONIAN)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The Group has six formations. Only the Arkona is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

QUEENSTON FORMATION (UPPER ORDOVICIAN)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are 12 large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa (Guillet 1967). All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

NEPEAN (POTSDAM) FORMATION (CAMBRO-ORDOVICIAN)

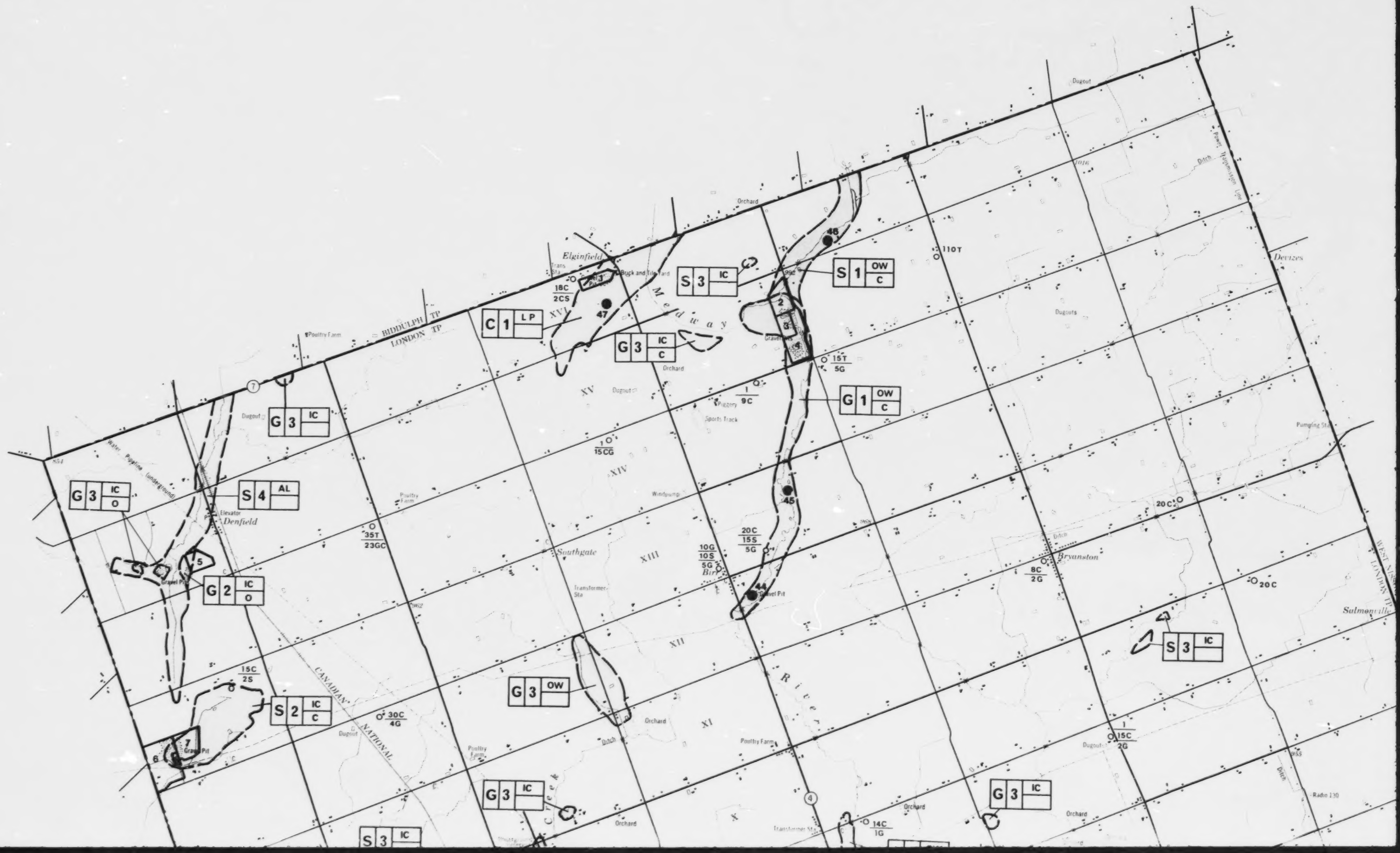
Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

SALINA FORMATION (UPPER SILURIAN)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. **Uses:** Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

WHITBY FORMATION (UPPER ORDOVICIAN)

(Formerly known as Collingwood Shale near Toronto). **Composition:** Brown to black fissile shale. **Uses:** Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggregate.





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Hon. Alan W. Pope
Minister

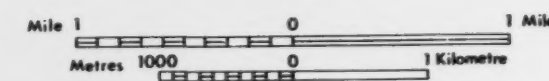
W.T. Foster
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

LONDON TOWNSHIP
MIDDLESEX COUNTY

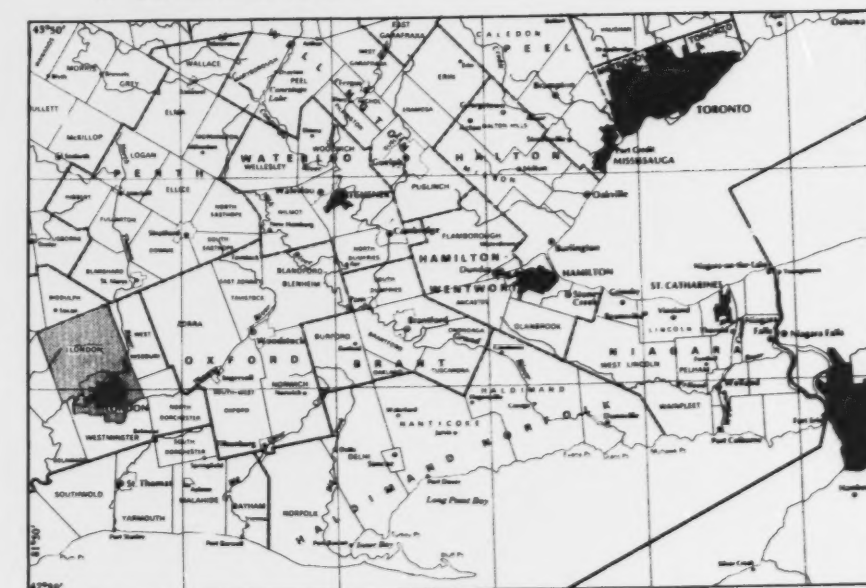
MAP 1
DISTRIBUTION OF SAND AND
GRAVEL DEPOSITS

Scale: 1:50,000



NTS Reference: 40 P/3, 40 I/14

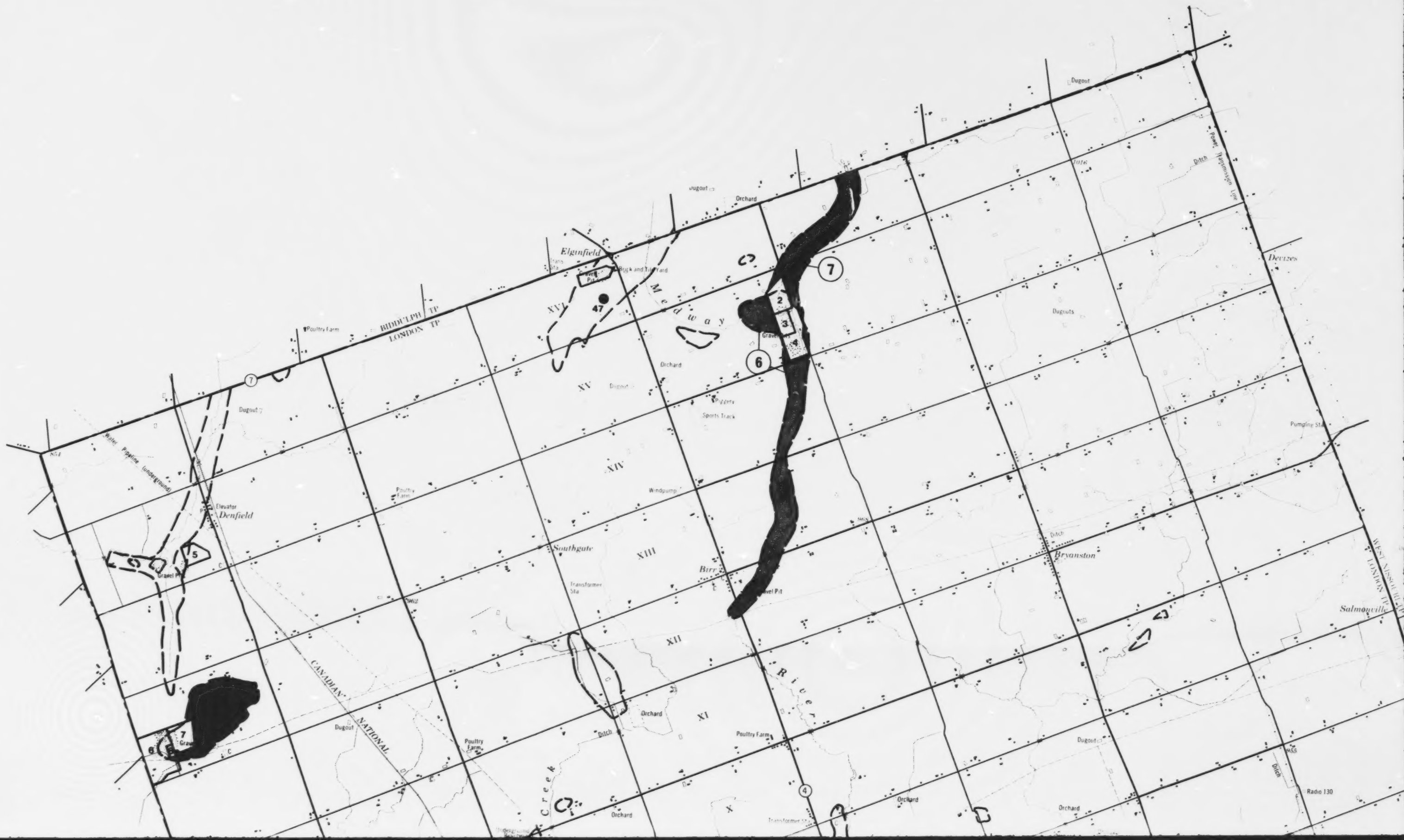
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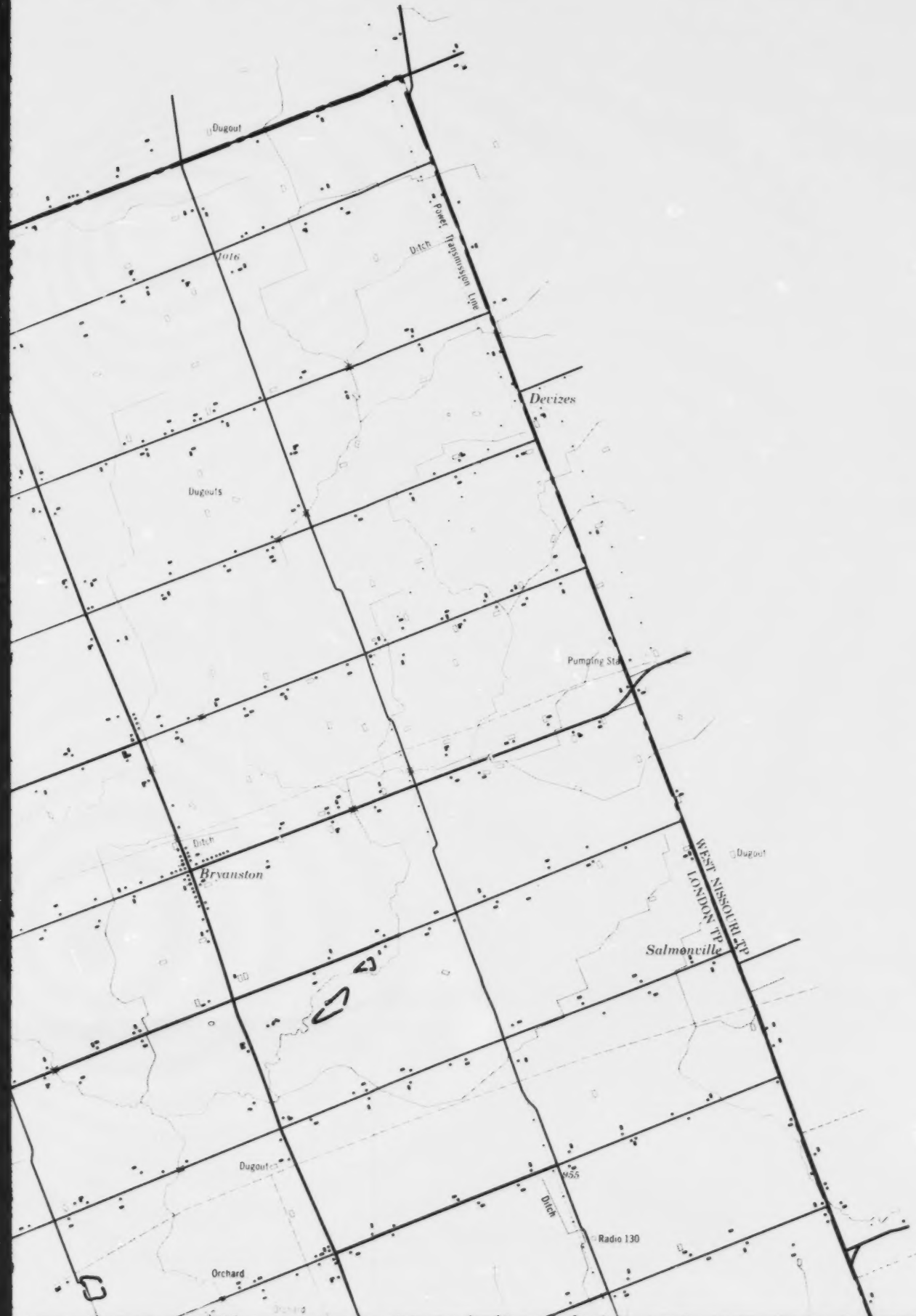


SYMBOLS

(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary. Shading indicates deposit area
- Deposit symbol: see below.
- Licenced property boundary; Property number: see Table 2.
- Unlicensed sand or gravel pit*; Property number: see Table 2
*Abandoned pit or wayside pit operating on demand under authority of a permit.
- Selected drilling location indicating thickness of overburden overlying reported thickness of granular materials (in feet). (Note: S - sand, G - gravel, T - till)





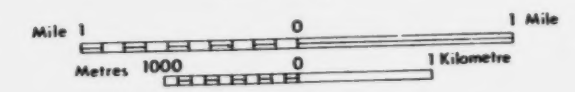
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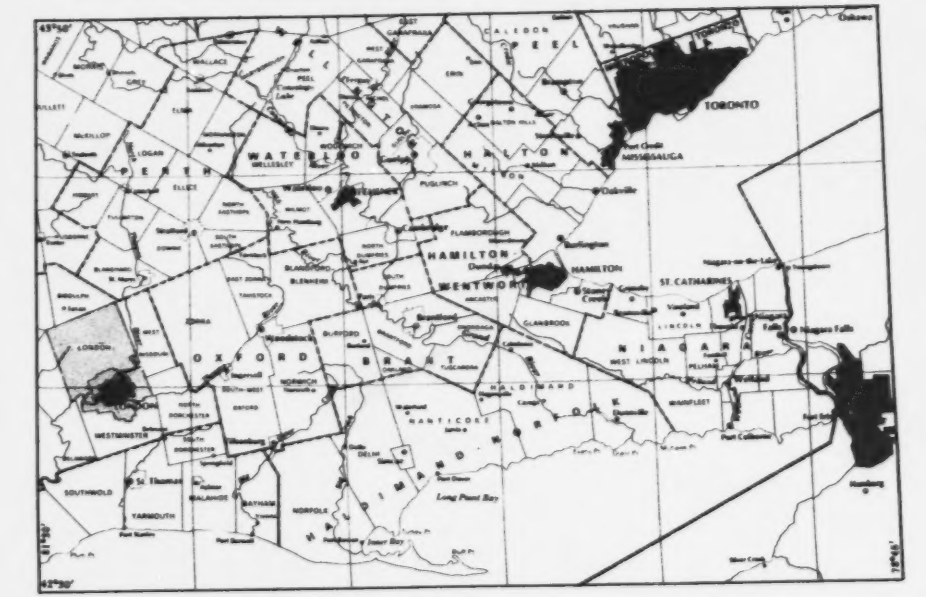
LONDON TOWNSHIP
MIDDLESEX COUNTY

MAP 2
SELECTED SAND AND GRAVEL
RESOURCE AREAS
Scale: 1:50,000



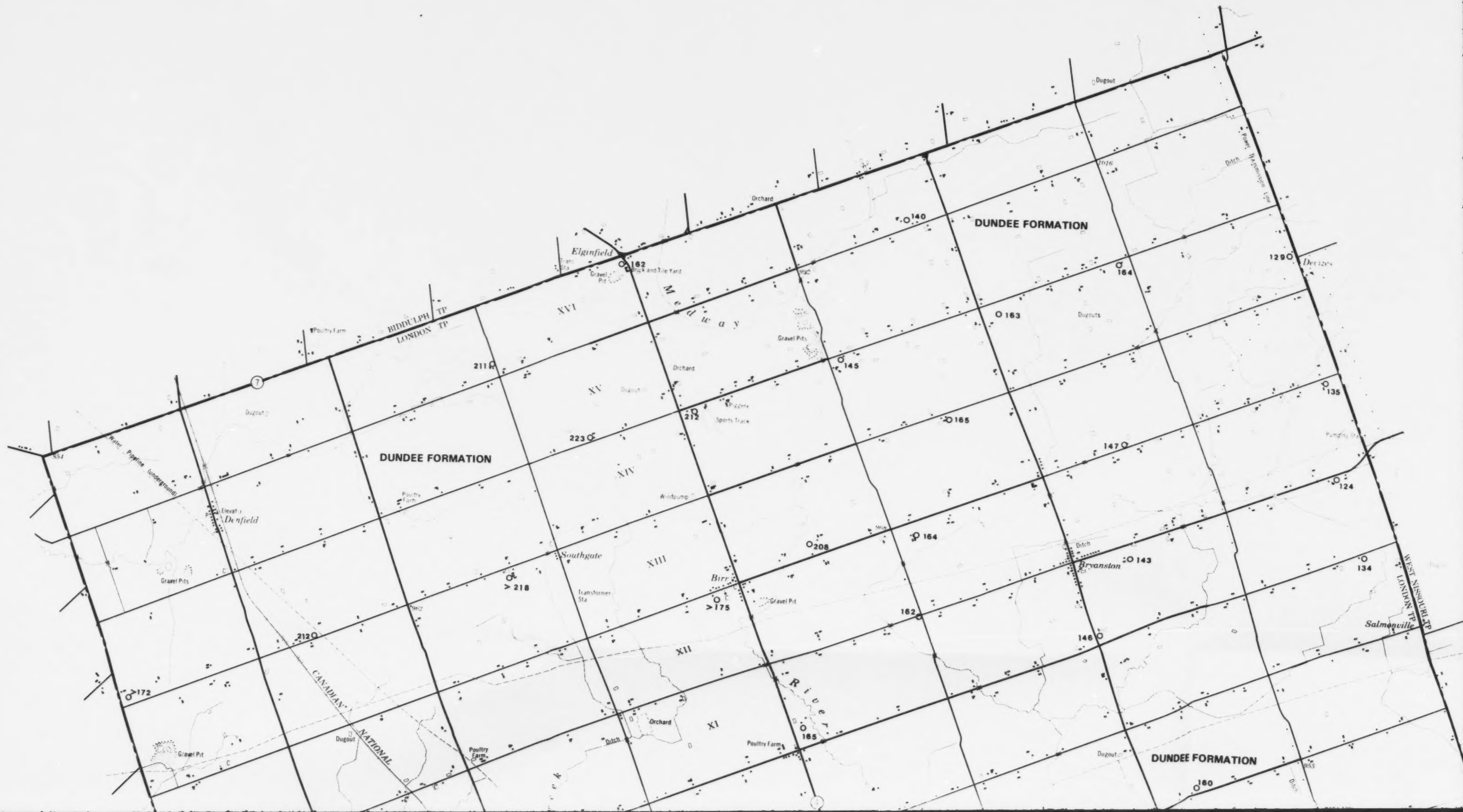
NTS Reference: 40 P/3, 40 I/14

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SYMBOLS
(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary.
- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area; Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- Licenced property boundary; Property number: see Table 2.
- Unlicenced sand or gravel pit*; Property number: see Table 2.
- *Abandoned pit or wayside pit operating on demand under





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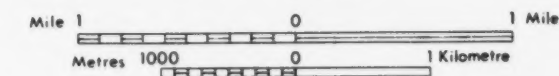
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MIDDLESEX COUNTY

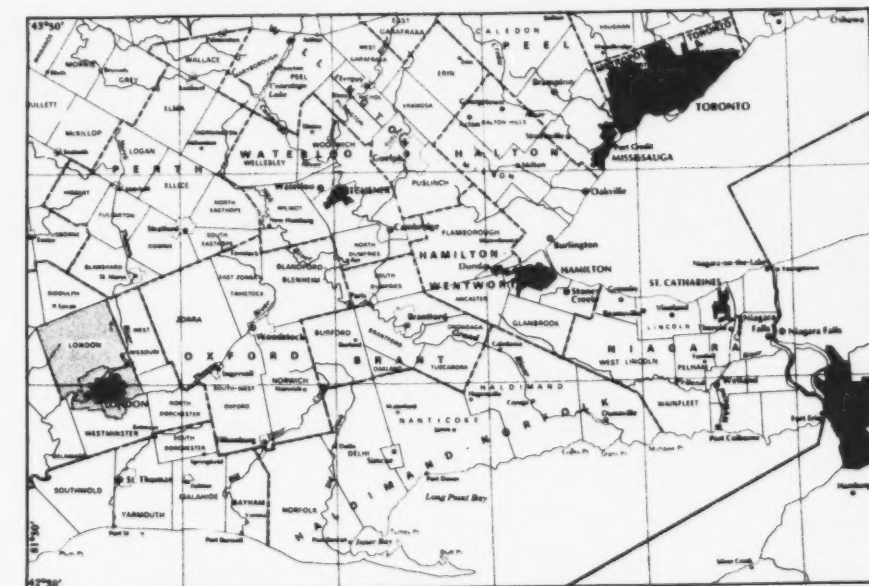
MAP 3
BEDROCK RESOURCES

Scale: 1:50,000



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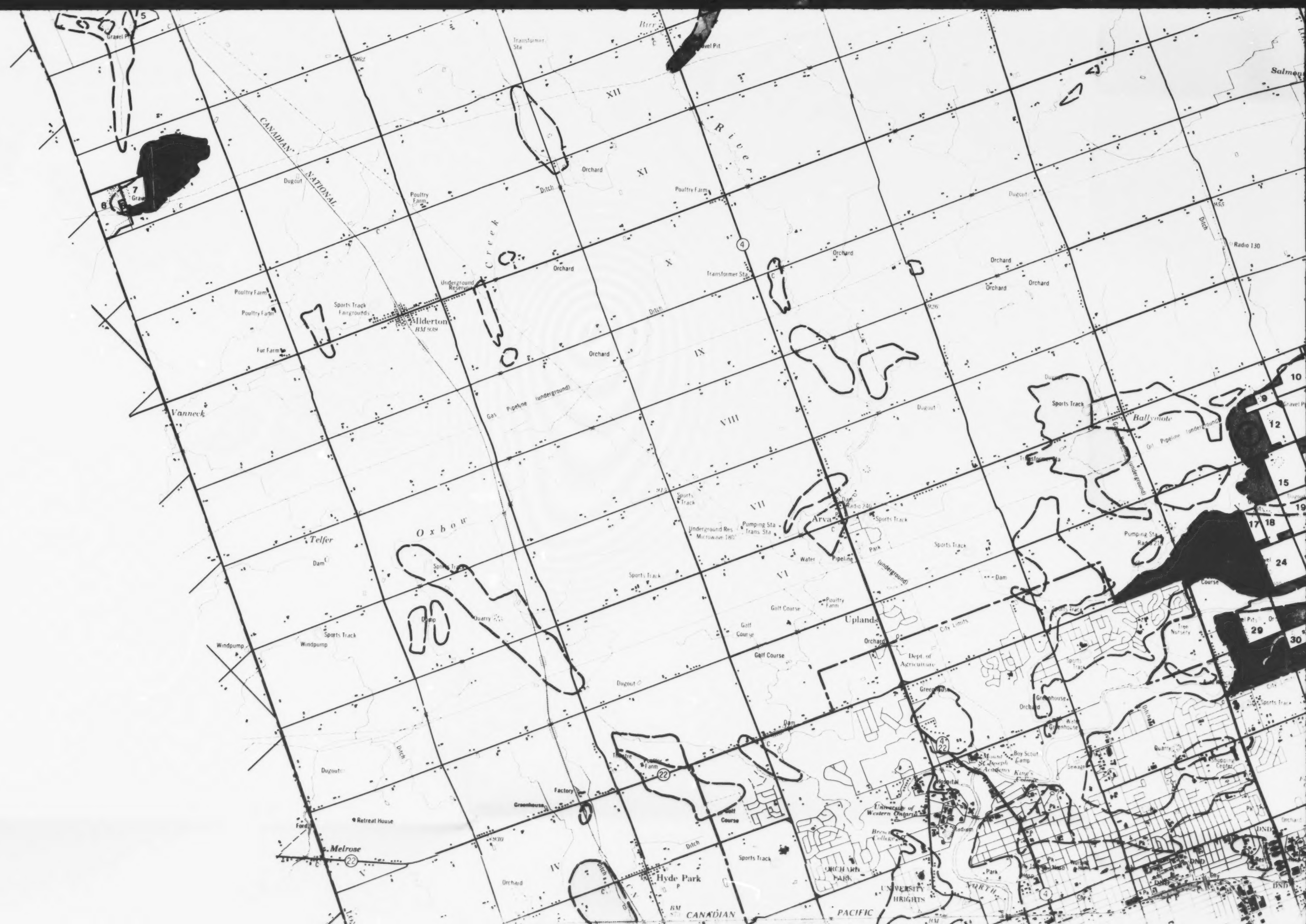
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LEGEND

PALEOZOIC
DEVONIAN
MIDDLE DEVONIAN

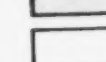
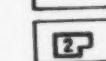
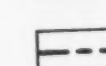






SYMBOLS

(Some symbols may not apply to this map)

-  Geological and aggregate thickness boundary.
-  Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
-  Selected sand and gravel resource area; Secondary significance.
-  Selected sand and gravel resource area; Tertiary significance.
-  Licenced property boundary; Property number: see Table 2.
-  Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.
-  Municipal boundary.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected drilling data from the Ontario Ministry of the Environment and the Petroleum Resources Section, Ontario Ministry of Natural Resources.

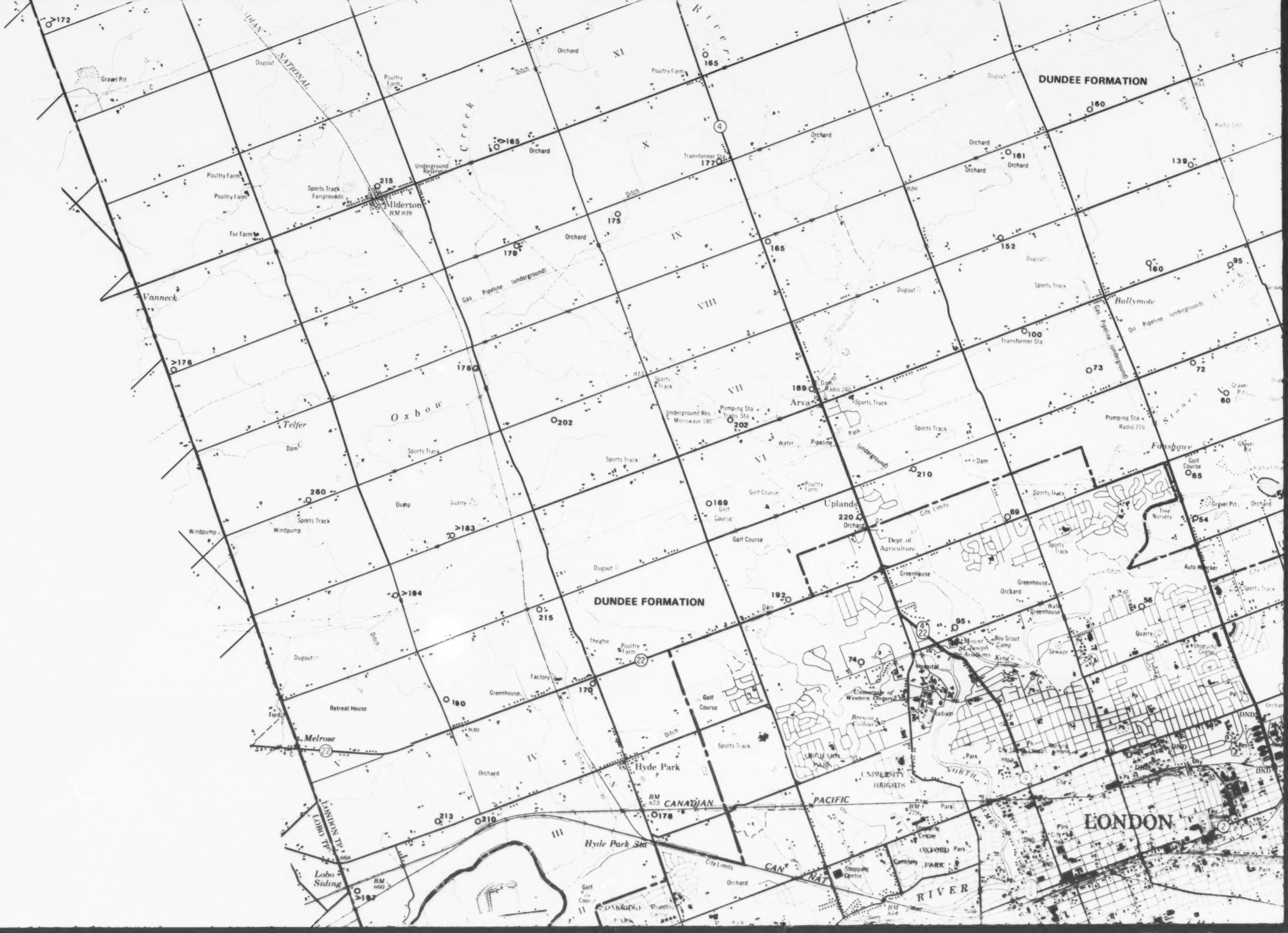
Geology by: A. Dreimanis, 1964, 1968, 1970
E.V. Sado and U.J. Vagners, 1975

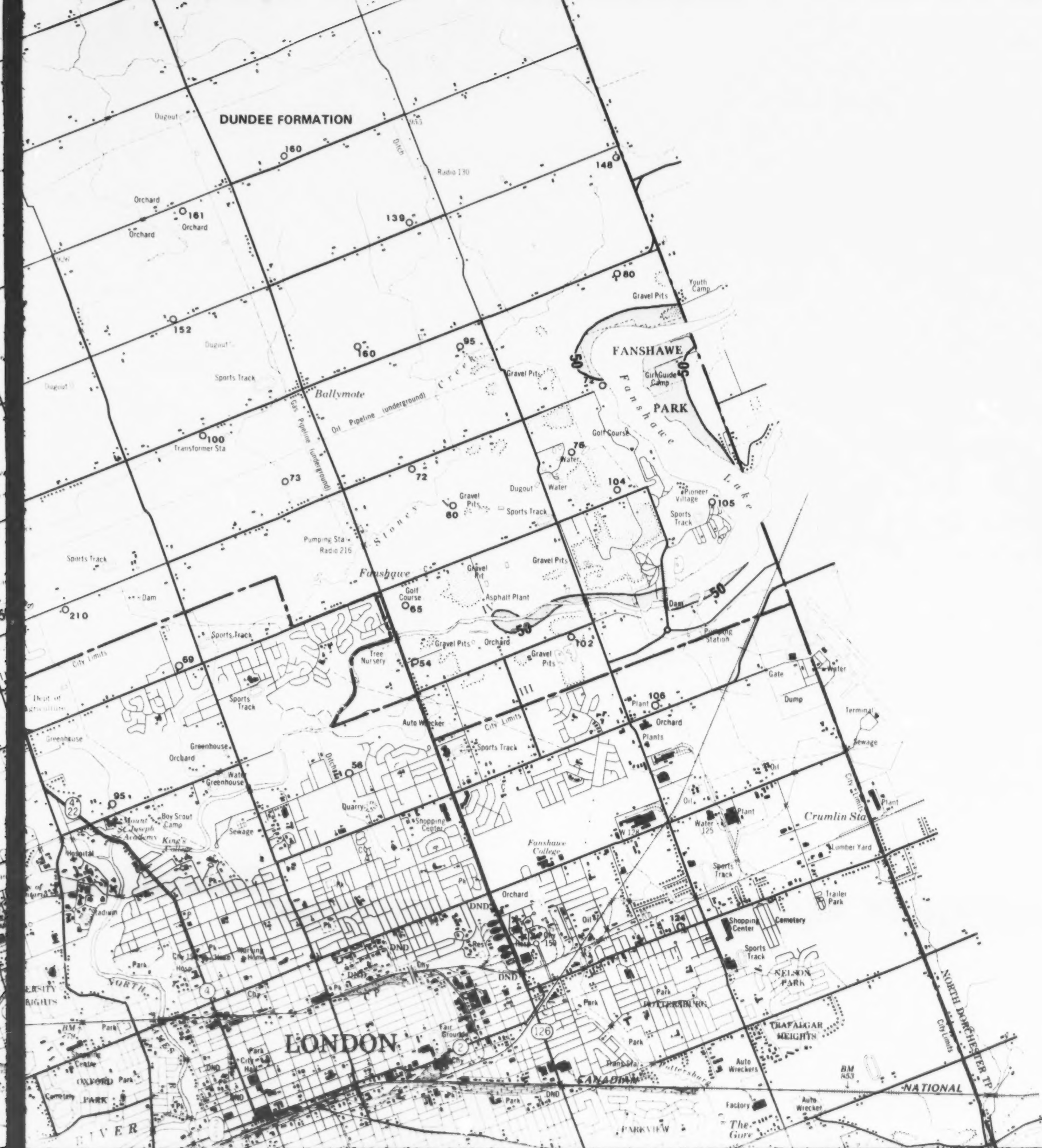
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LEGEND

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

DUNDEE FORMATION Limestone

SYMBOLS

(Some symbols may not apply to this map.)

-  Geological boundary.
-  Drift thickness contour line (25 foot (8 m) interval).
-  Isolated bedrock outcrop.
-  Bedrock within 3 feet (1 m) of surface: see Table 4.
-  Bedrock covered by 3 to 25 feet (1 m to 8 m) of overburden: see Table 4.
-  Bedrock covered by 25 to 50 feet (8 m to 15 m) of overburden: see Table 4.
-  Selected bedrock resource area; Deposit number: see Table 6.
-  Licenced quarry boundary; Property number: see Table 5.
-  Unlicenced quarry*; Property number: see Table 5.
*Abandoned quarry or wayside quarry operating on demand under authority of a permit.
-  Selected drilling location indicating reported depth to bedrock (in feet).
-  Municipal boundary.

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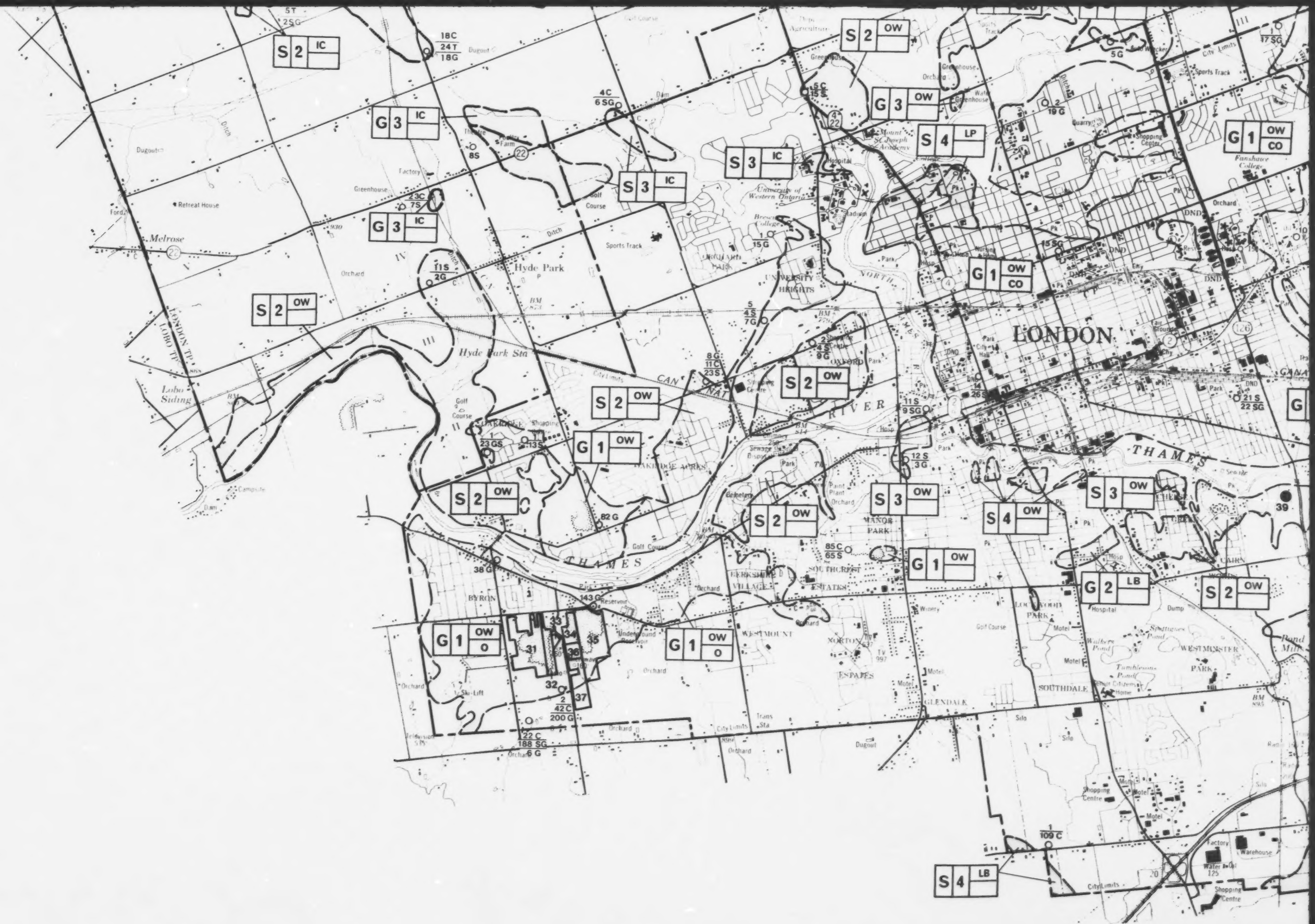
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E.V. Sado and D. Jones, 1980.
B.V. Sanford, 1969

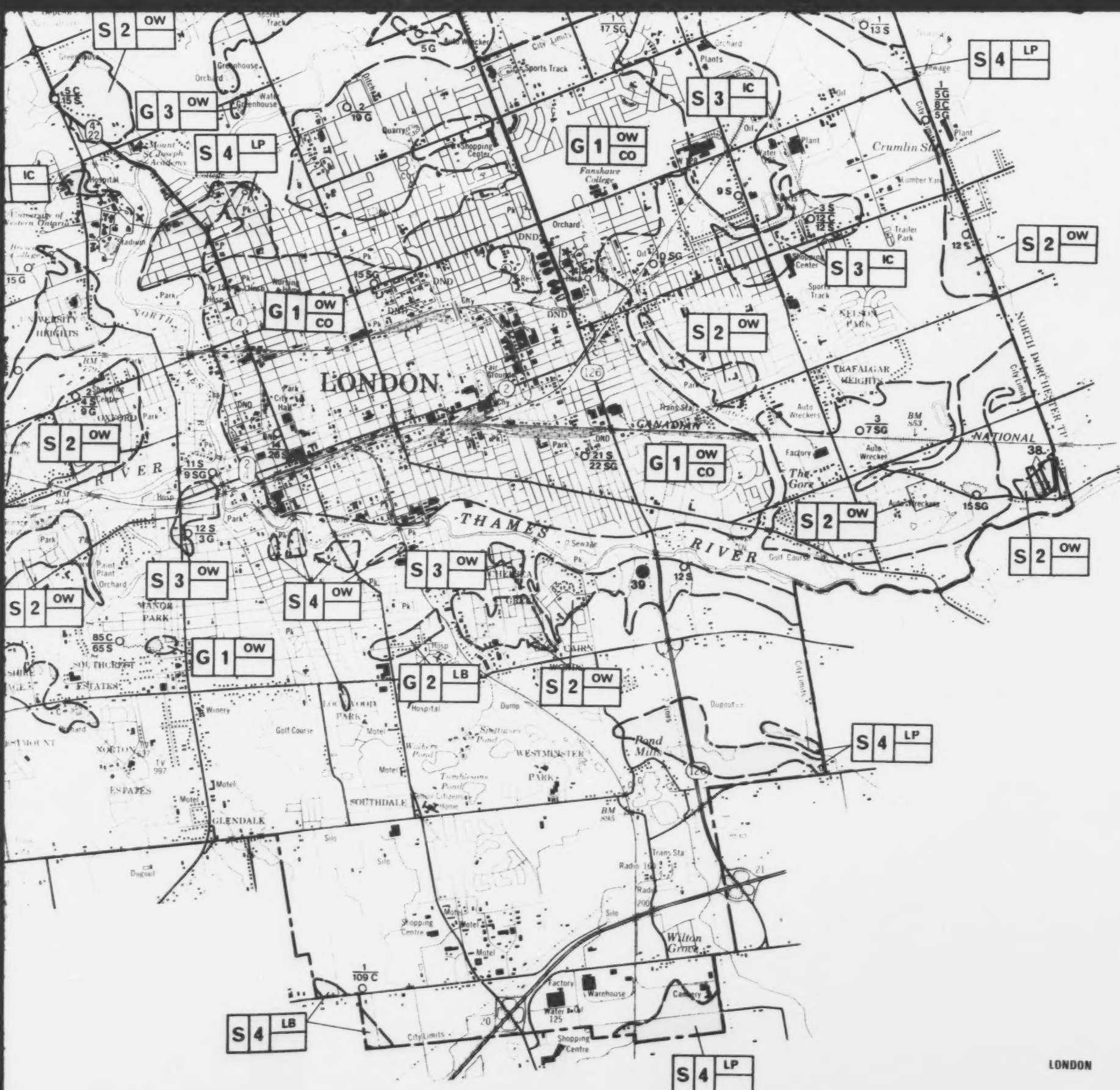
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1	greater than 20 (> 6)	greater than 50,000 (>112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500-25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12,500 (<28 000)

Geological Type

IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
ICT	Ice-Contact Terrace	LB	Lacustrine Beach
K	Kame	LP	Lacustrine Plain
E	Esker	LD	Lacustrine Delta
EM	End Moraine	AL	Older Alluvium
		WD	Windblown Forms

(see Appendix C for descriptions of Geological Types.)

Quality Indicators

	If blank, no known limitations present
C	Clay and/or silt (fines) present in objectionable quantities
L	Deleterious lithologies present
O	Oversize particles or fragments present in objectionable quantities

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LONDON





--- Municipal boundary.

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